The features so far mentioned will be dealt with in detail in future papers, and the main purpose of this communication is to report the remarkable result in September 1958 when the rate increased practically from winter to summer values within two days when the satellite was at a height of approximately 400 km.

An abrupt seasonal change in the ionosphere at this time of the year has been known for many years and has been consistently observed in travelling disturbance studies[3]. An examination of the available records for September 1958 did indeed show a marked change in direction of movement at this time, and also a correspondingly marked rise in critical frequency at Australian ionosonde stations. These results are shown in Fig. 2. There are some gaps in the data, but the conclusion is clear. It appears that the directional change occurred first, followed a day later by the change in rate, with the critical frequency change becoming obvious a day later again. Some fluctuation in direction after the main seasonal change is usual.

This sequence suggests a major change in the movement of ionization at this epoch which appears to be consistent with a reversal of the north–south seasonal component of drift indicated by travelling disturbances. Since this change occurred during the Geophysical Year, examination of records at other sites should yield interesting information. A magnetic storm of world-wide incidence but short duration occurred about this time, and its relation to the general change is being examined.

These results indicate the value of simple satellite observations, as a supplement to ionosonde recordings, for ionospheric studies and predictions. The 20 Mc./s. frequency band seems very satisfactory and an orbit such as that of *Explorer VII* is particularly suitable. Its height-range is 350–670 miles and this is swept through every 50 days in each transit at any site. The type of transmission used—continuous-wave with frequency modulation—is also satisfactory. The pulsed transmissions from *Sputnik III* made counting difficult at high rates, but short closely spaced pulses, as used in part of the coding of *Sputnik IV*, would be satisfactory and would enable study of multiple paths. Occasional breaks would be useful also for this purpose and for comparison of spaced receiver records. Telemetry information could also be conveyed as at present.

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[1] Munro, G. H., and White, R. B., *Nature*, **181**, 104 (1958).
[2] Munro, G. H., and Heisler, L. H., *Nature*, **183**, 809 (1959).
[3] Munro, G. H., *Aust. J. Phys.*, **11**, 1, 91 (1958).

Observations of 'Whistlers' and 'Chorus' at the South Pole

Whistlers and chorus are now being observed at the South Geographic Pole (79° geomagnetic), and the seasonal and diurnal variations in occurrence of these phenomena at this unique location follow interesting and perhaps significant patterns.

Maximum chorus activity occurred during the midsummer period, gradually diminished through February and March, and virtually disappeared when the Sun dropped below the horizon. Despite this seasonal dependence on solar zenith angle, there was a surprising and considerable diurnal variation in both strength and occurrence of chorus with a consistent maximum between 1500 and 1600 U.T. corresponding to approximately 1000 hr. local magnetic time.

No whistlers were apparent during the summer period, and it was not until March 8 that the first whistler was heard. Whistlers became quite prevalent after sunset, and the rate of occurrence increased through April and May to reach a maximum during the winter solstice. A considerable and consistent diurnal variation is apparent with maximum activity centred about 0630 U.T.

Although detailed characteristics of these polar whistlers cannot be determined until the tape recordings are available for spectrographic analyses, aural monitoring indicates that they generally resemble whistlers at lower latitudes. Pure tones, swishes and multiples are most common. Echo trains with about 2½ sec. delay between events were heard on May 10 and May 31. The rate of occurrence at Pole Station (averaging 2–3 per min. during active periods) is comparable with typical whistler-rates at middle-latitude stations.

Judging from the observed characteristics of these polar whistlers, it appears that they could have been produced at lower latitudes, reaching the receiver by reflexion between the Earth and lower ionosphere[1,2]. The seasonal and diurnal variations in the occurrence of whistlers at the South Pole may therefore be due to the seasonal and diurnal variations in D region absorption over the path of propagation. Assuming that the whistlers are propagated more readily along the path of least absorption, the diurnal peak at 0600 U.T. at Pole Station suggests that the whistlers penetrate the ionosphere somewhere along the 70° meridian, probably in the vicinity of Graham Land, approximately 55° south geomagnetic latitude. In middle latitudes whistler-rates are generally higher at night and in local winter, and therefore consistent with the hypothesis that D region absorption affects whistler propagation. If this interpretation is correct, coincidence should exist between whistler occurrences at South Pole Station and Port Lockroy. This will be investigated when the recordings from both stations are available for analyses.

The origin, or origins, of chorus are not fully understood. The seasonal variation of this phenomenon at the South Pole, with maximum activity occurring in midsummer, suggests direct dependence on solar radiation. It seems probable, therefore, that the polar chorus signals are initiated by solar corpuscular radiation impinging on the outer ionosphere.

The association between very-low-frequency hiss and aurora observed at Byrd Station, Antarctica, is also apparent at Pole Station[3]. However, whereas the auroral hiss observed at Byrd Station usually centres about a frequency of 8 kc./s., at Pole Station, 10° higher in geomagnetic latitude, the auroral hiss centres about 9·5 kc./s. This change in frequency of auroræ-associated hiss with latitude is interesting. At 42° south geomagnetic Ellis[4] has associated very-low-frequency noise at 4–6 kc./s. with auroræ, and current investigations also indicate that the frequency of auroræ-associated hiss may decrease with geomagnetic latitude.

The very-low-frequency observations at Pole Station are being made by Oliver C. Morse of the United States Antarctic Research Program. The work reported in this communication is supported by National Science Foundation Grant G-9511.

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[1] Martin, L. H., *Nature*, **181**, 1796 (1958).
[2] Ungstrup, E., *Nature*, **184**, 806 (1959).
Martin, L. H., Helliwell, R. A., and Marks, K. R., *Nature*, **187**, 751 (1960).
[4] Duncan, R. A., and Ellis, G. R., *Nature*, **183**, 1618 (1959).

GEOLOGY

Olivine–Spinel Transition on Nickel Orthosilicate

THE pressure-induced transition of olivine to a denser spinel structure is probably of considerable importance in the Earth's mantle[1]. Olivine–spinel transitions are known in Mg_2GeO_4 (refs. 2 and 3) and Fe_2SiO_4 (ref. 1), while a variety of evidence indicates that Mg_2SiO_4 will undergo a similar transition around 125,000 atmospheres and 600° C. (refs. 1 and 3). These results suggested the desirability of exploring for olivine–spinel transitions in other substances which normally crystallize with an olivine structure.

Such a substance is nickel orthosilicate—Ni_2SiO_4. From preliminary[1] and recent (Ringwood, A. E., unpublished results) data on the solid solubility of Ni_2SiO_4 in Ni_2GeO_4 (spinel) and vice versa, I have calculated that Ni_2SiO_4 should undergo an olivine–spinel transition around 54,000 atmospheres at 1,500° C. However, Wentorf[4] has recently reported unsuccessful attempts to synthesize a spinel modification of Ni_2SiO_4 at pressures up to 110,000 atmospheres. I have carried out further high-pressure experiments using a uniaxial pressure apparatus (squeezer), in an attempt to resolve the conflict, and provide further information on olivine–spinel transitions.

Intimate mixtures of $Ni(OH)_2$ and silicic acid in orthosilicate ratios were prepared, and subjected to pressures between 0 and 50,000 atmospheres, at 650° C., for periods between 1 and 6 hr. Fourteen runs were made. After completion of a run, the pressure was rapidly released, while the sample was quenched and then examined by X-ray diffraction.

At pressures below 15,000 atmospheres the phases observed were Ni_2SiO_4 olivine, NiO, and nickel talc. It may be shown that the last two products constitute a metastable assemblage, due to incomplete reaction. Above 20,000 atmospheres, olivine disappeared and in its place a spinel phase appeared, together with NiO and talc. Between 15,000 and 20,000 atmospheres, spinel, olivine, talc and NiO appeared simultaneously. A run at 50,000 atmospheres, using a mix containing 20 per cent excess $Ni(OH)_2$ over that required to form the normal orthosilicate, produced spinel and NiO. Talc was absent.

A sample of Ni_2SiO_4 olivine was prepared by sintering a tablet of intimately mixed NiO and SiO_2 at 1,400° C. for 6 hr. The tablet was then crushed, reformed and resintered, this procedure being repeated twice. A sample thus prepared was subjected to 50,000 atmospheres and 700° C. for 2½ hr. About 80 per cent conversion to the spinel form was observed. Similar runs were carried out at 30,000 and 20,000 atmospheres. A small amount of spinel formed at 20,000 atmospheres, but curiously, no spinel formed at 30,000 atmospheres.

Mixtures of silicic acid, hydrous germanium dioxide, and nickel hydroxide were prepared at intervals in the composition range between Ni_2GeO_4 and Ni_2SiO_4. These were run at 33,000 atmospheres and 650° C. A complete series of spinel solid solutions was found to exist between Ni_2GeO_4 (normally a spinel) and Ni_2SiO_4. The solid solutions obeyed Vegard's law.

It is concluded that the new phase is the spinel modification of Ni_2SiO_4 and that the equilibrium pressure for the olivine–spinel transition in Ni_2SiO_4 at 650° C. is about 18,000 atmospheres. Ni_2SiO_4 spinel is green, transparent, and has a lattice parameter of 8·044 Å. The calculated density is 5·34 gm./c.c., which is about 9 per cent higher than that of the olivine modification.

The experimental transition pressure is in good agreement with the value calculated (54,000 atm.) from zero pressure equilibria at 1,500° C. in the system $Ni_2GeO_4 - Ni_2SiO_4$ if a reasonable allowance is made for the effect of temperature on transition pressure. A detailed description of equilibria in this system, and the calculations based upon it, will be published elsewhere.

Wentorf's failure to synthesize Ni_2SiO_4 spinel at much higher pressures than I used may be due to the different type of apparatus employed[5]. We both used mixtures of $Ni(OH)_2$ and silicic acid as starting materials, and operated at temperatures sufficiently high to cause the components to react and form Ni_2SiO_4. However, the uniaxial device which I used permits rapid quenching—in particular, the water vapour pressure can be instantaneously released. Published descriptions[5] suggest that Wentorf's apparatus may not have been able to quench the reaction products as quickly; furthermore, the quenching may be carried out in the presence of a high pressure of water vapour (from the pyrophyllite pressure medium). Thus it is possible that any spinel formed at high pressures afterwards became inverted to olivine during the quench.

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[1] Ringwood, A. E., *Geochim. et Cosmochim. Acta*, **13**, 303; **15**, 18, 195 (1958).
[2] Goldschmidt, V. M., *Nachr. Ges. Wiss. Göttingen*, **1**, 184 (1931).
[3] Dachille, F., and Roy, R., *Amer. J. Sci.*, **258**, 225 (1960).
[4] Wentorf, R. H., *Nature*, **183**, 1617 (1959).
[5] Bovenkerk, H. P., Bundy, F. P., Hall, H. T., and Wentorf, R. H., *Nature*, **184**, 1094 (1959).

Potassium–Argon Ages of Some Rocks from the South Atlantic

THE ages of micas separated from a number of rocks from the South Orkney Islands have been determined using the potassium–argon method.

In these particular measurements, the total volume of argon evolved on fusion of the samples was measured by means of a McLeod gauge, and a correction applied for atmospheric contamination using a mass spectrometer to resolve the argon isotopes. Potassium analyses were made with a flame photometer.